SUBSTITUTE SPECIFICATION

LASER ELEMENT DRIVING APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a laser element driving apparatus that controls the light emission (lighting) of a laser element, and more particularly relates to a laser element driving apparatus that controls the light emission of a laser element that takes into consideration safety in relation to the human eye.

2. Description of the Related Art

[0002] Digital cameras, digital videos and the like use laser elements as backlights for focusing on nighttime photographic subjects. This kind of laser element driving apparatus that controls the light emission of a laser element generally includes a laser element and a photodetection element, which monitors and converts to electric signals the light intensity thereof, and the supply current to the laser element is controlled by feeding back the electric signal of the photodetection element (see, for example, Japan Patent Application Laid-open No. H6-326396). Moreover, the laser element driving apparatus intermittently

supplies current to the laser element, and correspondingly causes the laser element to emit light discontinuously.

[0003] FIG. 2 is a conventional laser element driving apparatus. This laser element driving apparatus 101 includes a laser element LD that varies the light intensity corresponding to the current that flows thereto; a photodetection element PD that receives the light, which the laser element LD emits, and generates a current corresponding to the light intensity; a voltage conversion resistor 130 that converts the current of the photodetection element PD to voltage; a feedback amplifier 112 that controls an emission control switch 111, to be described later, by receiving at a non-inversion input terminal the voltage of the voltage conversion resistor 130 and receiving at an inversion input terminal a voltage output from an emission intensity setting voltage generator 124 for setting the emission intensity of the laser element LD; the emission control switch 111 that is a PMOS transistor to control the current that flows to the laser element LD, wherein the gate receives the output voltage of the feedback amplifier 112, and the drain is connected to the laser element LD; and a power source switch 125 that is an NPN transistor that opens and closes (becomes non-conductive, conductive) corresponding to an intermittent control signal SIG including a low level and a high level, wherein the collector is connected to a power source Vdd and the emitter is connected to

an inner power source VddIN. The source of the emission control switch 111 and the power source terminal of the feedback amplifier 112 are connected to the inner power source VddIN.

[0004] The operation of the laser element driving apparatus 101 will be explained next. When a low level intermittent control signal SIG is input to the power source switch 125, the power source switch 125 becomes non-conductive and no power is fed to the emission control switch 111. Consequently, no current flows to the laser element LD and the laser element LD does not emit light. When a high level intermittent control signal SIG is input to the power source switch 125, the power source switch 125 becomes conductive, and the inner power source VddIN becomes the predetermined power voltage. Immediately after the power source switch 125 becomes conductive, no current is produced by the photodetection element PD, and therefore the input voltage of the non-inversion input terminal of the feedback amplifier 112 is at ground level, and the output voltage of the feedback amplifier 112 is also at ground level. Consequently, the emission control switch 111 is turned on, current flows to the laser element LD, and the laser element LD emits light. Then, based on the feedback loop, when the voltage of the voltage conversion resistor 130 reaches the output voltage of the emission intensity setting voltage generator 124, a predetermined current stably

flows to the laser element LD. This operation repeats corresponding to the intermittent control signals SIG.

[0005] In this way, a laser element LD, which is used in a digital camera, digital video or the like, emits light discontinuously (intermittently) by the laser element driving apparatus 101. This is in order to prevent deleterious effects on the eyes of a person who is the photographic subject.

[0006] The present inventor focused on the possibility that a laser element could be in a continuously lit state if trouble were to occur with the intermittent control signal SIG or the like. In such a situation, it would be preferable to establish a countermeasure so as not to enter a continuously lit state. Moreover, as previously stated, immediately after the power source switch 125 has become conductive, the output voltage of the feedback amplifier 112 is at ground level, and therefore the emission control switch 111 is turned fully on so that the maximum current flows. The present inventor focused on the possibility of light emission in which, as a result, current rushes into the laser element and the emission intensity becomes excessively large, and discovered a countermeasure so that an excessively large emission will not occur even in this situation.

SUMMARY OF THE INVENTION

[0007] In order to overcome the problems described above, preferred embodiments of the present invention provide a laser element driving apparatus that prevents long-term light emission (continuous lighting) or high intensity light emission of a laser element having deleterious effects on the human eye, and that heightens safety in relation to the human eye.

[0008] The laser element driving apparatus according to a preferred embodiment of the present invention includes a laser element that varies light intensity corresponding to a current that flows thereto; a photodetection element that monitors and converts to electric signals the light intensity of the laser element; an emission control switch that controls the current flowing to the laser element; a feedback amplifier that controls the emission control switch by feeding back electric signals of the photodetection element; and an emission control switch controlling circuit that turns the emission control switch OFF when determining as abnormal a current flowing continuously to the laser element for a predetermined time from the beginning of the laser element light emission and/or that controls the emission control switch such that the current flowing to the laser element at the time of beginning of the laser element light emission is gradually increased.

[0009] Preferably, the emission control switch controlling circuit includes an emission stop switch in order to turn OFF the emission control switch by determining as abnormal a current flowing continuously to the laser element for a predetermined time from the beginning of the laser element light emission.

[0010] Moreover, the emission control switch controlling circuit preferably includes a capacitor and a light emission stop switch in order to control the emission control switch such that the current flowing to the laser element is gradually increased when the laser element begins to emit light. When the laser element begins to emit light, the emission control switch is forced to turn OFF and the capacitor is charged by turning the emission stop switch ON, and after a predetermined time has elapsed, the emission control switch is controlled by turning the emission stop switch OFF and discharging the capacitor, and then the current flowing to the laser element is gradually increased.

[0011] More preferably, this laser element driving apparatus includes an oscillator that outputs a reference clock for counting the predetermined time from the beginning of the laser element light emission up to the determination of abnormality. This oscillator is made to stop the oscillation operation when the abnormality is determined.

[0012] According to another preferred embodiment of the present invention, the laser element driving apparatus stops the

light emission of the laser element LD by turning the emission control switch OFF when the laser element has emitted light continuously for a predetermined time or more based on a trouble of an intermittent control signal or the like. Therefore the safety in relation to human eyes can be heightened by preventing abnormally continuous light to have a deleterious effect on human eyes. Moreover, the current flowing to the laser element when the laser element begins to emit light is gradually increased, and therefore light with a large emission intensity is prevented from having a deleterious effect on human eyes, and the safety in relation to the human eye can be heightened. In addition, the life time of the laser element can be increased by minimizing the stress on the laser element.

[0013] Other features, elements, steps, characteristics and advantages of the present invention will become more apparent from the following detailed description of preferred embodiments of the present invention with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is a circuit diagram of a laser element driving apparatus according to a preferred embodiment of the present invention.

[0015] FIG. 2 is a circuit diagram of a conventional laser element driving apparatus.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0016] A preferred embodiment of the present invention will be described below by referring to FIG. 1. FIG. 1 is a circuit diagram of a laser element driving apparatus according to a preferred embodiment of the present invention. In the same way as the laser element driving apparatus 101 of the prior art, this laser element driving apparatus 1 includes a laser element LD that varies a light intensity corresponding to the current that flows thereto; a photodetection element PD that receives the light that the laser element LD emits and generates a current corresponding to the light intensity (specifically, monitors and converts to electric signals the light intensity of the laser element); a voltage conversion resistor 30 that converts the current of the photodetection element PD to voltage; a feedback amplifier 12 that controls an emission control switch 11, to be described later, by receiving at a non-inversion input terminal the voltage of the voltage conversion resistor 30 (that is, feeding back the electric signal of the photodetection element) and receiving at an inversion input terminal a voltage output from an emission intensity setting voltage generator 24 for setting the emission intensity of the laser element LD; the emission control switch 11 that is a PMOS transistor to control the current that flows to the laser element LD, wherein the gate

receives the output voltage of the feedback amplifier 12, and the drain is connected to the laser element LD; and a power source switch 25 that is an NPN transistor that opens and closes (becomes non-conductive, conductive) corresponding to an intermittent control signal SIG (for example, 50% duty rectangular waveform of about 50 Hz) including a low level and a high level, wherein the collector is connected to a power source Vdd and the emitter is connected to an inner power source VddIN. The source of the emission control switch 11 and the power source terminal of the feedback amplifier 12 are connected to the inner power source VddIN.

[0017] This laser element driving apparatus 1 further includes an oscillator (OSC) 17 that outputs a reference clock (for example 40 kHz); a fail-safe circuit 13 for preventing abnormal continuous lighting, which receives the inputs of the inner power source VddIN and the reference clock; a soft start circuit 14 for preventing excessively large current from flowing to the laser element LD, and which receives the inputs of the intermittent control signal SIG and the reference clock; and an emission control switch controlling circuit 16 that receives the signals from the fail-safe circuit 13 and the signals form the soft start circuit 14, and controls the emission control switch 11 based on these signals.

[0018] The fail-safe circuit 13 includes an inner power source detection circuit 18, a counter 19, and a flip flop circuit 20. The inner power source detection circuit 18 includes a capacitor 31 and resistor 33, which form a differentiation circuit, and a diode 32 that clamps the output voltage thereof. The inner power source VddIN is input to one end of the capacitor 31 as a signal. The other end of the capacitor 31 is connected to one end of the resistor 33 and the cathode of the diode 32. The other end of the resistor 31 and the anode of the diode 32 are grounded. The capacitor 31 and the resistor 33, which form the differentiation circuit, detect a rise of the inner power source VddIN, and generate a one shot pulse synchronized thereto, which is output to the counter 19 and the reset input terminal R of the flip flop circuit 20. The diode 32 prevents an excessively large load on the circuit receiving the output voltage by clamping the output voltage in the negative direction, which is produced synchronously with the fall of the inner power source VddIN, at the voltage below the ground potential by a Schottky barrier voltage (VF).

[0019] The one shot pulse of the inner power source detection circuit 18, as a count start signal, is input to the counter 19 of the fail-safe circuit 13, which counts the number of the reference clock of the oscillator 17. Then, when the predetermined count number (for example, a count of about 4000)

is reached, a signal is output to the set input terminal S of the flip flop circuit 20 to be explained below. The flip flop circuit 20 has a reset input terminal R and a set input terminal S as input terminals, and has a non-inversion output terminal Q and an inversion output terminal QN as output terminals. Low level is output from the non-inversion output terminal Q and high level is output from the inversion output terminal QN when a pulse is input to the reset input terminal R. High level is output from the non-inversion output terminal Q and low level is output from the inversion output terminal QN when a pulse is input to the set input terminal S. The signal of the non-inversion output terminal Q is input to one input terminal of the NOR circuit 28, to be described later, of the emission control switch controlling circuit 16. The signal of the inversion output terminal QN is input to the oscillator 17, the oscillator 17 is oscillated if the signal is high level, and the oscillator 17 does not oscillate, or stops oscillating, if the signal is low level.

[0020] The circuit configuration of the soft start circuit 14 will be explained next. The soft start circuit 14 includes an intermittent control signal detection circuit 21, a counter 22, and a flip flop circuit 23. The intermittent control signal detection circuit 21 is configured in the same way as the inner power source detection circuit 18. That is, the intermittent

control signal detection circuit 21 includes a capacitor 34 and a resistor 36, which form a differentiation circuit, and a diode 35 that clamps the output voltage thereof. The capacitor 34 and the resistor 35, which form the differentiation circuit, detect a rise of the intermittent control signal SIG, and generate a one shot pulse synchronized thereto, which is output to the counter 22 and reset input terminal R of the flip flop circuit 23.

[0021] The one shot pulse of the intermittent signal detection circuit 21, as a count start signal, is input to the counter 22 of the soft start circuit 14, which counts the number of the reference clock of the oscillator 17. Then, when the predetermined count number (for example, a count of about 4) is reached, a signal is output to the set input terminal S of the flip flop circuit 23 to be explained below. The flip flop circuit 23 conducts the same function as the flip flop circuit 20 of the previously described fail-safe circuit 13. The signal of the inversion output terminal QN is input to the other input terminal of the NOR circuit 28 of the emission control switch controlling circuit 16, and the signal of the non-inversion output terminal Q is not input to anywhere.

[0022] The circuit configuration of the emission control switch controlling circuit 16 will be explained next. The emission control switch controlling circuit 16 includes the NOR circuit 28, which receives, as previously described, the input of

signals from the flip flop circuit 20 of the fail-safe circuit 13 and signals from the flip flop circuit 23 of the soft start circuit 14; an emission stop switch 29 that is a PMOS transistor, wherein the source is connected to the inner power source VddIN, and the drain is connected to the output of feedback amplifier 12; and a soft start capacitor 38, wherein one end is connected to the drain thereof, and the other is grounded. The current drive capacity of the emission stop switch 29 is sufficiently higher than the current drive capacity of the ground side (specifically, the sink current side) of the feedback amplifier 12. According to this configuration, if either of the two signals input to the NOR circuit 28 is a high level signal, the emission stop switch 29 is turned ON, and, irrespective of the output of the feedback amplifier 12, the gate of the emission control switch 11 is forced to the power source voltage level. As a result, a current does not flow to the laser element LD, and the soft start capacitor 38 is charged to the power source voltage level. Meanwhile, if both of the two signals input to the NOR circuit 28 are low level, the emission stop switch 29 turns OFF, and therefore the gate voltage of the emission control switch 11 is determined by the status of the feedback amplifier 12 and the soft start capacitor 38. This will be explained in detail below.

[0023] The operation of the laser element driving apparatus 1 will be explained next. First, if a low level intermittent control signal SIG is input to the power source switch 25, the power source switch 25 becomes non-conductive, and no power is supplied to the emission control switch 11. Consequently, no current flows to the laser element LD, and the laser element LD does not emit light.

[0024] Next, when the laser element LD begins to emit light, specifically, when a high level intermittent control signal SIG is input to the power source switch 25, the power source switch 25 becomes conductive, and the inner power source VddIN becomes the predetermined power source voltage. Then, the rising edge of the inner power source VddIN is detected by the inner power source detection circuit 18 of the fail-safe circuit 13, the flip flop circuit 20 is reset by the detection signal thereof, and the counter 19 begins counting.

[0025] Meanwhile, the rising edge of the intermittent control signal SIG is detected by the intermittent control signal detection circuit 21 of the soft start circuit 14, and the flip flop circuit 23 is reset by the detection signal and the counter 22 starts counting. When the flip flop circuit 23 of the soft start circuit 14 is reset, the high level from the inversion output QN of the flip flop circuit 23 is input to the NOR circuit 28 of the emission control switch controlling circuit 16. The

NOR circuit 28 outputs low level to the emission stop switch 29, the emission stop switch 29 is turned ON, and the gate of the emission control switch 11 becomes the power source voltage level. At that time, the emission control switch 11 is OFF (non-conductive), and therefore no current can flow to the laser element LD. The soft start capacitor 38 is charged to the power source voltage level. The laser element LD does not emit light, and no current is generated by the photodetection element PD, and therefore, the input voltage of the non-inversion input terminal of the feedback amplifier 12 is at ground level, and the feedback amplifier 12 outputs at ground level. Consequently, the sink current (for example, about 100 μA) of the feedback amplifier 12 flows unchanged through the emission stop switch 29, but, as previously described, the current drive capacity of the emission stop switch 29 is sufficiently high, and therefore, the gate voltage of the emission control switch 11 is maintained at the power source voltage level.

[0026] Next, when the counter 22, which has begun to count, counts up (for example, a count of about 4) to a predetermined time (for example, about 0.1 msec) that is shorter than one cycle of the intermittent control signal SIG (for example, 20 msec), a high level is input to the set input S of the flip flop circuit 23. The low level from the inversion output QN of the flip flop circuit 23 is input to the NOR circuit 28 of the emission control

switch controlling circuit 16. Moreover, the low level from the non-inversion output Q of the flip flop circuit 20 of the fail-safe circuit 13, which was reset, is input to the other input terminal of the NOR circuit 28. The NOR circuit 28 outputs the high level, and causes the emission stop switch 29 to turn OFF. Further, during the predetermined time (for example, about 0.1 msec) determined by the counter 22, the inner power source VddIN rises sufficiently and the soft start capacitor 38 fully charges.

[0027] Then, the electric charge charged at the soft start capacitor 38 (for example, 0.01 μF) is gradually discharged by the sink current (for example, about 100 μA) of the feedback amplifier 12, and the gate voltage of the emission control switch 11 gradually drops. In this way, the emission control switch controlling circuit 16 controls the emission control switch 11 to gradually increase the current that flows to the laser element LD when the laser element LD begins to emit light.

[0028] In this way, the laser element driving apparatus 1 can prevent the deleterious effect of high intensity light emission on the human eye by gradually increasing the current which flows to the laser element LD and causing no rush of current to flow to the laser element LD when the laser element LD begins to emit light. Moreover, long-lasting laser element life may be expected because stress on the laser element caused by the rush of current is minimized.

[0029] Next, the emission intensity of the laser element LD gradually increases in conjunction with the gradual decrease of the gate voltage of the emission control switch 11. Then, the current that the photodetection element PD generates becomes large, and the voltage of the voltage conversion resistor 30 gradually heightens. If this voltage becomes larger than the output voltage of the emission intensity setting voltage generator 24, the feedback amplifier 12 outputs, causing the gate voltage of the emission control switch 11 to rise. Specifically, when the voltage of the voltage conversion resistor 30 and the output voltage of the emission intensity setting voltage generator 24 coincide, the predetermined current stably flows to the laser element LD based on a feedback loop.

[0030] The operation described above is repeated corresponding to the intermittent control signal SIG. Thus, the laser element LD is made to emit discontinuously (intermittently) in a stable manner so as to prevent a deleterious effect on human eyes.

[0031] Here, if trouble occurs with the intermittent control signals SIG or the like, and the inner power source VddIN does not fall within a predetermined time (for example, about 0.1 sec), the counter 19 of the fail-safe circuit 13 reaches the predetermined count number (for example, a count of about 4000). In this case, a high level is input to the set input S of the flip flop circuit 20, and the high level from the non-inversion

output Q is input to the NOR circuit 28 of the emission control switch controlling circuit 16. Then, the low level from the NOR circuit 28 is input to the emission stop switch 29, and the emission stop switch 29 is turned ON. The emission control switch 11 is thereby turned OFF, a current does not flow to the laser element LD, and emission stops. Specifically, a current flowing continuously to the laser element LD for a predetermined time (for example, about 0.1 sec) from the time the laser element LD begins to emit light is determined to be abnormal, and the emission control switch 11 is turned OFF to stop emission of the laser element LD.

[0032] In this way, if the laser element LD continues to emit light for a predetermined time or more based on a trouble with the intermittent control signal SIG or the like, by turning OFF the emission control switch 11 and stopping the emission of the laser element LD, the laser element driving apparatus 1 can safely drive the laser element LD to prevent a deleterious effect on human eyes even during abnormal operation.

[0033] Moreover, during abnormal operation, the low level from the inversion output QN of the flip flop circuit 20 is input to the oscillator 17, stopping the oscillation operation. This is because it is not necessary for the oscillator to operate if the laser element LD is not allowed to emit light. In this way, it is possible to economize power consumption.

[0034] The present invention is not limited to the preferred embodiments described above, and a variety of design modifications are possible within the range of the elements described in the claims. For example, in the above preferred embodiments an apparatus having both a fail-safe circuit 13 and a soft start circuit 14 were provided, but the former may be omitted if countermeasures to prevent a trouble with the intermittent control signal SIG or the like are taken by another arrangement; and the latter may be omitted if countermeasures to prevent a rush of current to the laser element LD are taken by another arrangement. Moreover, naturally it is possible to increase or decrease the number of inverters or NOR circuits and the like by substituting the MOS transistor used in the laser element driving apparatus 1 with a bipolar transistor, or conversely, by replacing the bipolar transistor with a MOS transistor.

[0035] While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.